# TECHNICAL REPORT STANDARD TITLE PAGE

| 1. REPORT NO. | 2. GOVERNMENT ACCESSION NO. | 3. RECIPIENT'S CATALOG NO. |
|---|---|---|
| WA-RD 399.1 | | |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Automated Video-based Survey of Travel Times in HOV vs. General Purpose Lanes | October, 1995 |
| | 6. PERFORMING ORGANIZATION CODE |

| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
|---|---|
| Jeffrey B. Woodson, Paul W. Shuldiner, Salvatore A. D'Agostino | |

| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. WORK UNIT NO. |
|---|---|
| Transfomation Systems, Inc. 2537 S. Gessner, Suite 212 Houston, Texas 77063 | |
| | 11. CONTRACT OR GRANT NO. |
| | WSDOT Field Order No. F923805 |

| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
|---|---|
| Washington State Department of Transportation (WSDOT) Transportation Building, P.O. Box 47370 Olympia, Washington 98504-7370 | Final Technical Report |
| | 14. SPONSORING AGENCY CODE |

**15. SUPPLEMENTARY NOTES**

**16. ABSTRACT**

Transformation Systems, Inc. was hired to perform automated video-based travel time surveys for the high occupancy vehicle (HOV) and the adjacent general purpose (GP) traffic lane on two freeway corridors in the Seattle area. The purpose of the project was to demonstrate and test the use of machine-vision technology for travel time data collection. Evaluating techniques for determining travel times and speeds is necessary for the WSDOT to determine whether its HOV lane performance criteria are being met. The project used hi-8 video cameras to collect very-high quality video tapes of vehicle license plates. The video tapes were then processed at Computer Recognition Systems, Inc. in Cambridge, Massachusetts, with a specialized computer programmed to convert the video images into computer data files. The report details the video survey methodology; the data acquired through license plate recognition, including date, time, location, and direction of travel; and the comparison data used to determine respective travel times for HOV and GP traffic lanes.

The field data were collected from Monday, June 19, 1995, through Thursday, June 22, 1995, for each four-hour morning peak period (6:00-10:00 AM) on westbound SR 520 and for each four-hour evening peak period (3:00-7:00 PM) on northbound I-5. In all, over 90,000 license plates were analyzed, representing approximately 75 percent of the traffic volume. The license plate data were used to "match" vehicles between camera stations and to compute travel times on more than 200 vehicles per hour in high volume traffic conditions.

Results on northbound I-5 indicate that the evening peak period commute away from downtown Seattle in the GP lane can be 2.0 to 2.7 times longer than the same commute using the HOV facilities for the 5.75 kilometers (3.57 miles) of freeway monitored (between NE 117th and NE 185th Street). Results averaged over the four weekdays for the entire four-hour evening period indicate approximately 60 percent longer commute times in the GP lanes compared to HOV lanes (the I-5 inside HOV lane has a two-person minimum occupancy requirement).

Similar results on westbound SR 520 could not be statistically verified for the morning peak period because of the relatively low number of vehicles observed during the survey period (transit buses were not counted and the SR 520 outside HOV lane has a three-person minimum occupancy requirement). However, there was evidence of approximately 50 percent longer commute times in the GP traffic lanes between 7:30-8:00 AM than the vehicles observed in the HOV lane on SR 520 for the 1.75 kilometers (1.09 miles) of freeway monitored (between 92nd Ave. NE and 76th Ave. NE).

| 17. KEY WORDS | 18. DISTRIBUTION STATEMENT |
|---|---|
| travel times, HOV, high occupancy vehicle, general purpose lanes, GP lanes, video, license plates, machine vision, commute times. | No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22616 |

| 19. SECURITY CLASSIF. (of this report) | 20. SECURITY CLASSIF. (of this page) | 21. NO. OF PAGES | 22. PRICE |
|---|---|---|---|
| None | None | 43 | |

**Final Technical Report**
WSDOT Field Order No. F923805
Video Survey of Traffic Flow per the Attached Specifications (in Field Order)

# AUTOMATED VIDEO-BASED SURVEY
# OF TRAVEL TIMES IN HOV VS.
# GENERAL PURPOSE LANES

by

Jeffrey B. Woodson                  Paul W. Shuldiner
Transfomation Systems, Inc.     Transfomation Systems, Inc.

Salvatore A. D'Agostino
Computer Recognition Systems, Inc.

**Transfomation Systems, Inc.**
2537 S.Gessner, Suite 212
Houston, Texas 77063

Eldon L. Jacobson, Technical Monitor
Washington State Department of Transportation (WSDOT)
Environmental and Engineering Service Center
Traffic Office, Advanced Technology Branch

Prepared for

**Washington State Transportation Commission**
Department of Transportation
and in cooperation with
**U.S. Department of Transportation**
Federal Highway Administration
Federal Transit Administration

October 1995

# - TABLE OF CONTENTS -

## List of Figures

## List of Tables

**Washington State DOT; Traffic Office; Field Order No. F923805
"Automated Video-based Survey of Travel Times
in HOV vs. General Purpose Lanes"**

**Final Report**

## EXECUTIVE SUMMARY

This report documents the video-based traffic data collection procedures, results obtained from using a proprietary automatic license plate reader, and conclusions drawn about travel times from a survey completed for the Washington State Department of Transportation as part of an effort to evaluate the differences in travel times of HOV lanes that run parallel to general purpose traffic lanes for westbound SR-520 (in-bound rush hour) and northbound I-5 (out-bound rush hour) near the downtown Seattle area.

Traffic surveys were performed using automatic video-based systems which have been developed by *Transfomation Systems, Inc. (Transfo)* and Computer Recognition Systems, Inc. (CRS) in conjunction with the U.S. Department of Transportation (Volpe Center). Non-intrusive roadside travel time surveys were conducted from Monday, June 19th, 1995 through Thursday, June 22nd, 1995 for each morning peak period of four hours (6:00 - 10:00 AM) and each evening peak period of four hours (3:00 - 7:00 PM).

*Transfo* and CRS collected and analyzed over 90,000 license plates, approximately 75% of the traffic volume as calculated by the number of vehicle license plate "triggers" obtained using a machine vision system. These data were used to "match" vehicles between camera stations and compute travel times on more than 200 vehicles per hour in high volume traffic conditions.

Results indicate the evening peak period commute home from downtown Seattle on northbound I-5 can be 2.0 to 2.7 times longer on a given day than the same commute using the HOV facilities for the ~3 ½ miles of freeway monitored. Results averaged over the four weekdays for the entire four hour evening period indicate approximately 60% longer commute times in the general purpose lanes versus HOV lanes.

Similar results could not be statistically verified for the morning peak period on westbound SR-520 due to the relatively low number of vehicles observed using the HOV facilities during the survey period. However, there was evidence of approximately 50% longer commute times in the general purpose traffic lanes between 7:30 - 8:00 AM than the vehicles observed in the HOV lane on SR-520 for the ~1 mile of freeway monitored.

Average speeds of traffic flow ranged from a high of 66 mph during non-congested periods to as low as 19 mph during periods of heavy congestion with stop-and-go traffic. A few vehicles were calculated to have reached average speeds in excess of 80 mph.

Washington State DOT; Traffic Office; Field Order No. F923805
"Automated Video-based Survey of Travel Times
in HOV vs. General Purpose Lanes"

Final Report

## 1.0 INTRODUCTION

License plates have long been used by transportation engineers and planners as a source of data for origin-destination, travel time, and other traffic studies. Typically, these studies have required large numbers of field and office personnel with associated high manpower costs. Manual operations have often also been characterized by unacceptably high rates of error in data collection and processing, especially when large amounts of data are collected and analyzed in a short period of time.

Many of the shortcomings associated with the manual collection and processing of vehicle license plates can be overcome through the use of video camcorders and machine vision license plate readers. Modern video camcorders are capable of capturing very clear images on license plates on vehicles operating in high-speed, high-volume traffic.

These images can be converted to computer files by license plate readers with high levels of speed and accuracy. It takes a human operator ten hours or longer to read and transcribe one hour of video tape into a computer file; a plate reader can accomplish this task in less than one hour, which is ten times faster than an experienced human operator. Also, the automatic plate reader can continue, without fatigue, to process tapes at this rate continuously hour after hour after hour.

This report documents the data collection procedures, results obtained, and conclusions drawn from a travel time survey completed for the Washington State Department of Transportation as part of an effort to evaluate the differences in journey times of HOV lanes that run parallel to general purpose traffic lanes for westbound SR-520 (in-bound rush hour) and northbound I-5 (out-bound rush hour) near downtown the Seattle area.

## 2.0  BACKGROUND

### Traditional versus Automated Video-based O-D Survey Techniques

In the past, several alternative techniques have been used to perform O-D surveys. This section discusses these techniques along with their advantages and disadvantages as well as cost comparison against automatic license plate reading and traffic flow analysis using machine recognition systems.

### Laptop Computers

Using this technique, individuals are put out into the field, usually one per lane, to manually enter license plates. A simple routine can be written to attach the time when a person inputs a plate string. The input typically consists of the first four characters [often only for cars (not trucks) of a given syntax]. As an example, for a license 123 ABC, the person inputs 123A. This supposedly allows a person to keep up with the traffic flow and avoids bad entries due to the difficulty of getting all 6 (or 7) characters correct. However, in tests performed, the match rate for this technique is not adequate. Results typically indicate only 5-10 percent of the vehicles are input, and a match rate of 1-3 percent are usually obtained for the survey sample.

### Advantage

• Can be used for small amounts of data and very slow traffic

### Disadvantages

• Only partial data exists therefore Department of Motor Vehicles databases cannot be used
• No permanent record of the traffic flows exist
• Very poor match rate (typically one to three percent)
• Human error in data entry, particularly with traffic moving a speeds above 30 mph

### Cost Comparison

• Equal Number of People
• Similar Equipment Cost (laptops versus video cameras)
• Lower Processing Costs (but much less data)

## Manual Review of Video Tape

Using this technique, video tapes of traffic are recorded and then reviewed by people. The license plate numbers are entered into a database along with the time. Using this method of analysis requires between ten to twenty hours for an individual to review one hour of videotape. The difficulty comes from the need to jog and shuttle the tape (fast forward or reverse or to play and stop the tape) when a vehicle appears. For high speed traffic, a vehicle may appear on a tape for only one-quarter second or less. In this case, it becomes very difficult to stop the tape player with the vehicle in the field of view.

### Advantages

- Permanent record exists with videotape
- Can do DMV database mailings

### Disadvantages

- Costs associated with tremendous amount of man hours
- Manual data entry accuracy degrades with time
- Extended length of time to obtain results

### Cost Comparison

- Equal amount of equipment (video cameras instead of laptops)
- More expensive than automatic processing (rate charges from $25.00 to $50.00 per hour). At the rate of more than ten man hours to one hour of tape, this is equivalent to $250.00 to $500.00 per hour of tape processing.

## Automatic License Plate Reading and Traffic Flow Analysis

Using this technique, each lane of traffic is videotaped. The tapes are collected and processed through an automatic license plate reading system. This system generates data files that include the time, license plate, date, location, lane number and direction of traffic flow. A software program creates matches, origin- destinations and travel times. This information may then be used to perform other functions based on DMV databases. This approach often yields match rates in the twenty-five percent to fifty percent range.

An additional camera can be placed over the roadway looking across three to six lanes of traffic. This tape is fed into a second machine vision system. This system, called a traffic analysis system (TAS), provides data on a lane by lane basis of the number, class (three types: car, medium sized vehicles such as trucks and vans, and large vehicle such as tractor trailers), speed, density of the traffic flow and roadway occupancy. This traffic flow information can then be used to compare travel times to road conditions. The result of the automatic analysis is a very thorough, fast and dense traffic survey.

## Advantages

- Large amounts of accurate data
- Very fast survey turnaround time
- Allows DMV mailings (depending on DMV permission to access their databases-varies from state to state)
- Provides additional traffic flow statistics
- Provides permanent traffic record

## Disadvantages

- Some inaccuracy in plate reading may cause minor mailing errors of survey post cards

## Cost Comparison

- Equal amount of equipment
- Equal or lower amount of personnel
- Lower tape processing costs than manual approaches
- Lowest cost per match approach

## 3.0   SCOPE OF WORK

### Overall Scope of Work

Automated video-based travel time surveys were completed for the high occupancy vehicle (HOV) and adjacent general purpose (GP) traffic lanes on I-5 northbound during the afternoon peak, and the HOV and GP traffic lanes on SR-520 westbound during the morning peak for four (4) week days.  In addition to the video surveys taken in the field, the following tasks were also completed to ensure safe and efficient collection of traffic data:

- Consultation on the development of safe and efficient survey procedures and site locations with the Washington State Department of Transportation, various local authorities and the State Highway Safety Department.

- Processing video tape for license plate matching was performed automatically.

- Motor vehicle license plates were matched and travel times were computed to show comparisons between the HOV and GP traffic lanes during peak times.

- Preparation of summary data for each survey site and the final summary report for "Automated Video-Based Survey of Travel Times in HOV vs. GP Lanes".

### Survey Procedures

*Transfo* used survey procedures related to video-based surveying methods developed in conjunction with the U.S. Department of Transportation (Volpe Center).  Dr. Paul Shuldiner has extensive experience in this area, and has worked with the Volpe National Transportation Research Center on developing video-based survey methodologies for origin-destination and travel times.  Significant field work was completed in the Seattle area during this prior developmental work with the Puget Sound Regional Council and the Washington State Department of Transportation.

*Transfo* conducted travel time surveys for four (4) consecutive weekdays (4 hours during morning peak and 4 hours during afternoon peak) at four selected locations along I-5 and SR-520 in Seattle, WA.  The survey sites selected by Washington State DOT include NE 117th and NE 185th along I-5 (3.57 miles apart), and 92nd Avenue NE and 76th Avenue NE along SR-520 (1.09 miles apart).  Hi-8 video cameras were mounted on highway overpasses and directed downward over one (1) HOV lane and one (1) GP lane of freeway traffic passing underneath using one (1) camera per lane.  The camera operators took video tape images of the rear license plates of traffic moving away.

*Important Note: Thanks to the Washington State DOT for being responsible for site permits, traffic control, and police assistance as was required by local authorities.*

**Schedule of Activities**

- Sunday:
  Arrival, review of survey sites, site permits, and safety operations.

- Monday-Thursday AM:
  Conducted video surveys during the morning peak period on the following four (4) camera locations (refer to Figure 1) from 6:00 AM until 10:00 AM:

  1. Westbound SR-520 General Purpose lane at 92nd Avenue NE overpass.
  2. Westbound SR-520 HOV lane at 92nd Avenue NE overpass.
  3. Westbound SR-520 General Purpose lane at 76th Avenue NE overpass.
  4. Westbound SR-520 HOV lane at 76th Avenue NE overpass.

- Monday-Thursday PM:
  Conducted video surveys during the evening peak period on the following four (4) camera locations (refer to Figure 2) from 3:00 PM until 7:00 PM:

  1. Northbound I-5 General Purpose lane at NE 117th Street overpass.
  2. Northbound I-5 HOV lane at NE 117th Street overpass.
  3. Northbound I-5 General Purpose lane at NE 185th Street overpass.
  4. Northbound I-5 HOV lane at NE 185th Street overpass.

**Processing Video Tape**

Tapes collected from the automated video surveys (refer to Table 1) were processed by CRS to match license plates to a specific location and time. The processing consisted of playing the tapes through a proprietary license plate reading system. The end results of this process was a database consisting of license plate numbers and the time and location at which they were observed. This provided a database listing approximately 75% of the license plates of all vehicles traveling by the station at a particular date and time.

Travel times were computed by matching the observed license plate numbers from one camera station located upstream with the corresponding camera station located downstream of the traffic flow. This task was completed using an automatic license plate matching algorithm which provides averages and statistics for every 15 minute interval.

**Figure 1.    Location of Field Camera Stations for Morning Peak Period.**
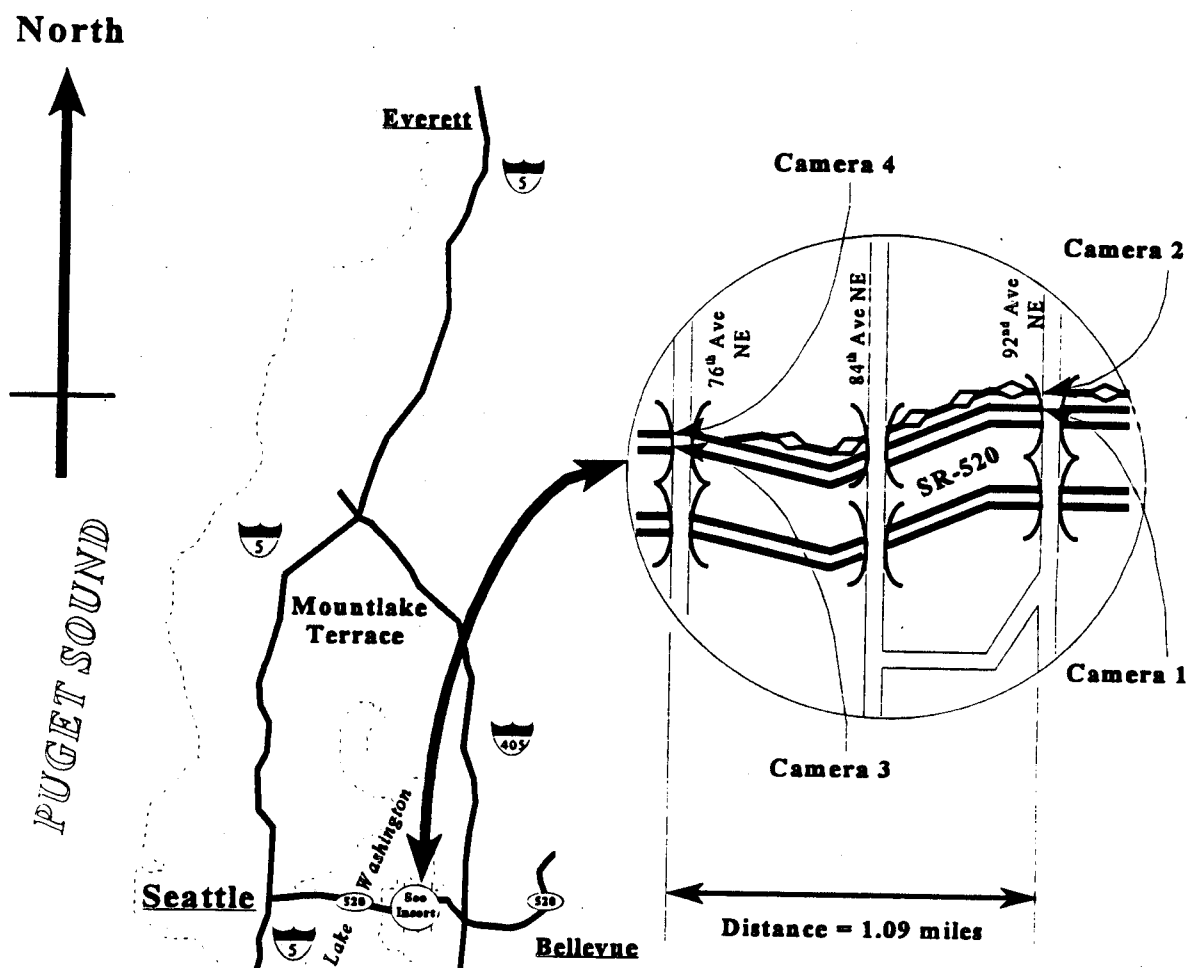
**Figure 2.    Location of Field Camera Stations for Evening Peak Period.**
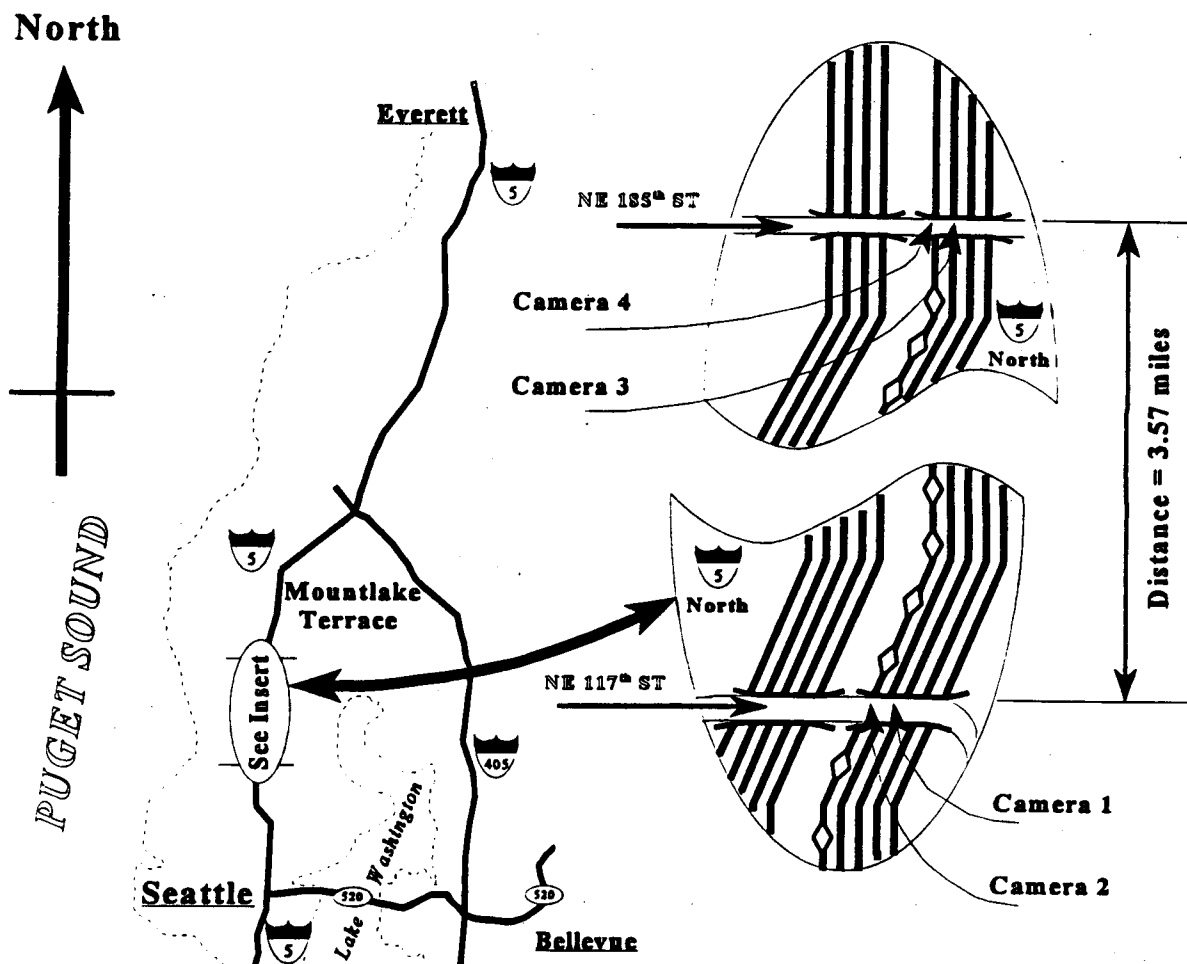
**Table 1.    Field Camera Stations, Tape Number, Directions, and Time of Day**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Field Camera Stations, Directions, and Time of Day | | | | |
| Tape No. | Date | Cam No. | Tape No. | Start Time | Adjusted Start Time | R - L<br>L - R<br>B - T | Operator | Location | Direction |
| 1 | 6/19/95 | 1 | 1 | 6:00:10 | 6:00:20 | B - T | Eldon | SR 520 @ 92nd | GP Lane - w/b |
| 2 | 6/19/95 | 1 | 2 | 8:01:00 | | B - T | Eldon | SR 520 @ 92nd | GP Lane - w/b |
| 3 | 6/19/95 | 1 | 3 | 2:57:00 | | B - T | Eldon | I-5 @ 117th | GP Lane - n/b |
| 4 | 6/19/95 | 1 | 4 | 4:57:45 | | B - T | Eldon | I-5 @ 117th | GP Lane - n/b |
| 5 | 6/19/95 | 2 | 1 | 6:00:50 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 6 | 6/19/95 | 2 | 2 | 8:00:30 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 7 | 6/19/95 | 2 | 3 | 2:57:30 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 8 | 6/19/95 | 2 | 4 | 4:58:15 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 9 | 6/19/95 | 3 | 1 | 6:07:30 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 10 | 6/19/95 | 3 | 2 | 8:00:00 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 11 | 6/19/95 | 3 | 3 | 3:03:00 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 12 | 6/19/95 | 3 | 4 | 5:00:30 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 13 | 6/19/95 | 4 | 1 | 6:02:00 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 14 | 6/19/95 | 4 | 2 | 7:58:00 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 15 | 6/19/95 | 4 | 3 | 3:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 16 | 6/19/95 | 4 | 4 | 5:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 17 | 6/20/95 | 1 | 1 | 6:00:00 | | B - T | Eldon | SR 520 @ 92nd | GP Lane - w/b |
| 18 | 6/20/95 | 1 | 2 | 8:01:00 | | B - T | Eldon | SR 520 @ 92nd | GP Lane - w/b |
| 19 | 6/20/95 | 1 | 3 | 2:59:30 | | B - T | Eldon | I-5 @ 117th | GP Lane - n/b |
| 20 | 6/20/95 | 1 | 4 | 5:00:00 | | B - T | Eldon | I-5 @ 117th | GP Lane - n/b |
| 21 | 6/20/95 | 2 | 1 | 6:00:50 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 22 | 6/8/95 | 2 | 2 | 8:01:30 | 8:18:30 | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 23 | 6/20/95 | 2 | 3 | 3:00:30 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 24 | 6/20/95 | 2 | 4 | 5:01:30 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 25 | 6/20/95 | 3 | 1 | 6:04:00 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 26 | 6/20/95 | 3 | 2 | 8:04:00 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 27 | 6/20/95 | 3 | 3 | 3:03:00 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |

| Tape No. | Date | Cam No. | Tape No. | Start Time | Adjusted Start Time | R - L L - R B - T | Operator | Location | Direction |
|---|---|---|---|---|---|---|---|---|---|
| 28 | 6/20/95 | 3 | 4 | 5:03:00 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 29 | 6/20/95 | 4 | 1 | 6:03:00 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 30 | 6/30/95 | 4 | 2 | 8:01:00 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 31 | 6/20/95 | 4 | 3 | 3:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 32 | 6/20/95 | 4 | 4 | 5:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 33 | 6/21/95 | 1 | 1 | 6:00:30 | | B - T | Eldon | SR 520 @ 92nd | GP Lane - w/b |
| 34 | 6/21/95 | 1 | 2 | 8:00:45 | | B - T | Eldon | SR 520 @ 92nd | GP Lane - w/b |
| 35 | 6/21/95 | 1 | 3 | 2:57:00 | | B - T | Eldon | I-5 @ 117th | GP Lane - n/b |
| 36 | 6/21/95 | 1 | 4 | 4:58:00 | | B - T | Eldon | I-5 @ 117th | GP Lane - n/b |
| 37 | 6/21/95 | 2 | 1 | 6:01:30 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 38 | 6/21/95 | 2 | 2 | 8:02:15 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 39 | 6/21/95 | 2 | 3 | 2:56:00 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 40 | 6/21/95 | 2 | 4 | 5:00:00 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 41 | 6/21/95 | 3 | 1 | 6:00:00 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 42 | 6/21/95 | 3 | 2 | 8:00:20 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 43 | 6/21/95 | 3 | 3 | 3:00:30 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 44 | 6/21/95 | 3 | 4 | 5:04:00 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 45 | 6/21/95 | 4 | 1 | 6:00:30 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 46 | 6/21/95 | 4 | 2 | 8:02:30 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 47 | 6/21/95 | 4 | 3 | 3:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 48 | 6/21/95 | 4 | 4 | 5:03:30 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 49 | 6/22/95 | 1 | 1 | 5:58:45 | | B - T | Paul | SR 520 @ 92nd | GP Lane - w/b |
| 50 | 6/22/95 | 1 | 2 | 8:00:00 | | B - T | Paul | SR 520 @ 92nd | GP Lane - w/b |
| 51 | 6/22/95 | 1 | 3 | 2:58:00 | | B - T | Paul | I-5 @ 117th | GP Lane - n/b |
| 52 | 6/22/95 | 1 | 4 | 4:59:00 | | B - T | Paul | I-5 @ 117th | GP Lane - n/b |
| 53 | 6/22/95 | 2 | 1 | 6:00:30 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 54 | 6/22/95 | 2 | 2 | 8:01:00 | | B - T | Perk | SR 520 @ 92nd | HOV Lane - w/b |
| 55 | 6/22/95 | 2 | 3 | 3:00:00 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |
| 56 | 6/22/95 | 2 | 4 | 5:01:00 | | B - T | Perk | I-5 @ 117th | HOV Lane - n/b |

10

| | | | | | | R - L | | | |
|---|---|---|---|---|---|---|---|---|---|
| header: Field Camera Stations, Directions, and Time of Day |

| Tape No. | Date | Cam No. | Tape No. | Start Time | Adjusted Start Time | R - L L - R B - T | Operator | Location | Direction |
|---|---|---|---|---|---|---|---|---|---|
| 57 | 6/22/95 | 3 | 1 | 6:01:30 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 58 | 6/22/95 | 3 | 2 | 8:03:00 | | B - T | Pedro | SR 520 @ 76th | GP Lane - w/b |
| 59 | 6/22/95 | 3 | 3 | 3:00:00 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 60 | 6/22/95 | 3 | 4 | 5:01:00 | | B - T | Pedro | I-5 @ 185th | GP Lane - n/b |
| 61 | 6/22/95 | 4 | 1 | 6:02:30 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 62 | 6/22/95 | 4 | 2 | 8:02:30 | | B - T | Jeff | SR 520 @ 76th | HOV Lane - w/b |
| 63 | 6/22/95 | 4 | 3 | 3:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |
| 64 | 6/22/95 | 4 | 4 | 5:00:00 | | B - T | Jeff | I-5 @ 185th | HOV Lane - n/b |

## 4.0 DISCUSSION OF RESULTS

### Tape Processing Procedures

Processing the camcorder tapes involved transferring the license plate images recorded on videotape at each camera station into a computer file along with the instant of time at which each license plate image was recorded. Each separate station file was then matched against a logically related file to obtain the number of vehicles traveling from one station to another and the interval for time required by each vehicle to accomplish this movement. Thus, for example, the license plates observed at Station 1 (GP lane upstream) were matched against the plates observed at Station 3 (GP lane downstream). Likewise, the license plates observed at Station 2 (HOV lane upstream) were matched against the plates observed at Station 4 (HOV lane downstream). The difference between the instant at which a given license was observed at the upstream station and the instant at which that same plate was observed at the downstream station is the travel time between those two stations for the vehicle carrying that license plate.

The percentage of the license plates passing a given camera location that can be successfully transferred from videotape images to a computer file depends on the quality of the videotape recording and the method used to effect that transfer. If the videotape license plate images are of very high quality, then processing by means of an automatic plate reader results in a relatively high percentage of these images being transferred directly to a computer file for subsequent analysis.

If, as was the case with about five percent of the videotapes in the present study, license plate images are in poor focus, or too dark (or bright), or are otherwise ill-suited for automatic reading, then other means of "reading" these images were employed. Wherever possible, the license plate images were automatically "captured" from the more comprehensive image of the vehicle and transferred to a separate view from which they could be read by a human operator and entered into a computer file. For those videotapes, or portions of tapes, for which the license plate images were unsuited for automatic "capture", human operators read license plates directly from the original tapes.

### Analysis of Results

### Observed Traffic Volume

The volume of traffic observed passing by each camera station was estimated by counting the number of vehicle plates which were obtained by processing the video tapes with a machine vision system. This system triggers whenever it "sees" a license plate. These data are presented in Table 2 on the following page.

*Information
Systems, Inc.*

**Table 2.   Observed License Plates Using Machine Vision Technology.**

| | | Observed License Plates Using Machine Vision | | |
| --- | --- | --- | --- | --- |
| Time of Day | Cam No. | Location | Direction | Number of Plates Read |
| 6 - 10 (AM Peak) | 1 | SR-520 @ 92$^{nd}$ | GP Lane - w/b | 12,141 |
| | 2 | SR-520 @ 92$^{nd}$ | HOV Lane - w/b | 534 |
| | 3 | SR-520 @ 76$^{th}$ | GP Lane - w/b | 16,822 |
| | 4 | SR-520 @ 76$^{th}$ | HOV Lane - w/b | 10,168 |
| Morning Total for SR-520 (in-bound) | | | | 39,665 |
| 2 - 6 (PM Peak) | 1 | I-5 @ 117$^{th}$ | GP Lane - n/b | 15,978 |
| | 2 | I-5 @ 117$^{th}$ | HOV Lane - n/b | 10,020 |
| | 3 | I-5 @ 185$^{th}$ | GP Lane - n/b | 15,254 |
| | 4 | I-5 @ 185$^{th}$ | HOV Lane - n/b | 10,152 |
| Evening Total for I-5 (out-bound) | | | | 51,404 |
| Project Total for License Plate Reads | | | | 91,069 |

**Travel Time Results**

Mean travel times from the originating stations to their respective destination station are presented in Tables 3 - 10 on the following pages. Statistical data on standard deviations and coefficients of variations can be found in Tables 3A - 10A in the Appendix. The number of observed and matched license plates are summed over the entire four day period in Tables 11 and 12, along with the "averaged" mean travel times and speeds.

Travel times generally vary with the ebb and flow of traffic volumes over the morning and evening peak periods of observation. A good example of this is seen in Table 8 (northbound I-5 traffic becoming congested around 5:00 PM), where travel time averages 200 seconds (corresponding to average speed of 64 mph) at 3:00 PM, rises to 940 seconds (dropping average speed to 14 mph) by 4:30 PM and remains high until 6:00 PM, and then drops to 230 seconds (increasing average speed back to 55 mph) by 7:00 PM.

In most instances, both the mean travel times and the coefficients of variation appear to be quite reasonable. The coefficients of variation associated with the various travel time estimates generally support the conclusion that these estimates accurately reflect the true value of mean travel time for each time period. Of the 206 calculated coefficients of variation (C.V.) only 6 are above 20 percent, and most C.V.'s are in the single digit range.

**Table 3.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
June 19, 1995 - 6:00 AM to 10:00 AM

| MORNING PEAK Time of Day A.M. | HOV LANE * | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds $t_{GP}-t_{HOV}$ | Ratio $t_{GP}/t_{HOV}$ |
| 6:00 - 6:15 | 3 | 0 | | | 76 | 4 | 62.8 | 62.5 | | |
| 6:15 - 6:30 | 7 | 1 | 52.0 | 75.5 | 192 | 23 | 66.6 | 58.9 | 14.6 | 1.3 |
| 6:30 - 6:45 | 8 | 4 | 53.5 | 73.3 | 209 | 21 | 66.5 | 59.0 | 13.0 | 1.2 |
| 6:45 - 7:00 | 8 | 1 | 51.0 | 76.9 | 215 | 19 | 67.2 | 58.4 | 16.2 | 1.3 |
| 7:00 - 7:15 | 16 | 2 | 46.0 | 85.3 | 237 | 16 | 70.9 | 55.3 | 24.9 | 1.5 |
| 7:15 - 7:30 | 17 | 8 | 49.3 | 79.6 | 268 | 31 | 73.3 | 53.5 | 24.0 | 1.5 |
| 7:30 - 7:45 | 24 | 5 | 46.6 | 84.2 | 251 | 33 | 86.2 | 45.5 | 39.6 | 1.9 |
| 7:45 - 8:00 | 24 | 2 | 44.5 | 88.2 | 200 | 29 | 77.1 | 50.9 | 32.6 | 1.7 |
| 8:00 - 8:15 | 2 | 1 | 73.0 | 53.8 | 211 | 22 | 73.3 | 53.5 | 0.3 | 1.0 |
| 8:15 - 8:30 | 2 | 1 | 74.0 | 53.0 | 212 | 17 | 70.0 | 56.1 | -4.0 | 0.9 |
| 8:30 - 8:45 | 3 | 1 | 72.0 | 54.5 | 195 | 8 | 68.0 | 57.7 | -4.0 | 0.9 |
| 8:45 - 9:00 | 2 | 1 | 74.0 | 53.0 | 201 | 15 | 66.3 | 59.2 | -7.7 | 0.9 |
| 9.00 - 9:15 | 4 | 1 | 68.0 | 57.7 | 205 | 22 | 65.1 | 60.3 | -2.9 | 1.0 |
| 9:15 - 9:30 | 3 | 1 | 67.0 | 58.6 | 179 | 14 | 66.6 | 58.9 | -0.4 | 1.0 |
| 9:30 - 9:45 | 0 | 0 | | | 239 | 30 | 70.2 | 55.9 | | |
| 9:45 - 10:00 | 0 | 0 | | | 194 | 14 | 66.4 | 59.1 | | |

* Excluding Transit Buses

**Table 4.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
June 20, 1995 - 6:00 AM to 10:00 AM

| MORNING PEAK Time of Day A. M. | HOV LANE * | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds $t_{GP}-t_{HOV}$ | Ratio $t_{GP}/t_{HOV}$ |
| 6:00 - 6:15 | 0 | 0 | | | 171 | 16 | 62.2 | 63.1 | | |
| 6:15 - 6:30 | 3 | 1 | 75.0 | 52.3 | 191 | 24 | 65.5 | 59.9 | -9.5 | 0.9 |
| 6:30 - 6:45 | 4 | 1 | 73.0 | 53.8 | 227 | 13 | 66.8 | 58.7 | -6.2 | 0.9 |
| 6:45 - 7:00 | 6 | 1 | 86.0 | 45.6 | 204 | 26 | 66.3 | 59.2 | -19.7 | 0.8 |
| 7:00 - 7:15 | 0 | 0 | | | 235 | 24 | 68.3 | 57.5 | | |
| 7:15 - 7:30 | 0 | 0 | | | 253 | 20 | 73.4 | 53.5 | | |
| 7:30 - 7:45 | 0 | 0 | | | 268 | 29 | 116.3 | 33.7 | | |
| 7:45 - 8:00 | 0 | 0 | | | 211 | 14 | 133.1 | 29.5 | | |
| 8:00 - 8:15 | 0 | 0 | | | 27 | 2 | 115.0 | 34.1 | | |
| 8:15 - 8:30 | 10 | 1 | 85.0 | 46.2 | 42 | 1 | 225.0 | 17.4 | 140.0 | 2.6 |
| 8:30 - 8:45 | 13 | 2 | 93.0 | 42.2 | 29 | 2 | 236.0 | 16.6 | 143.0 | 2.5 |
| 8:45 - 9:00 | 10 | 1 | 96.0 | 40.9 | 35 | 1 | 158.0 | 24.8 | 62.0 | 1.6 |
| 9:00 - 9:15 | 10 | 1 | 91.0 | 43.1 | 29 | 1 | 81.0 | 48.4 | -10.0 | 0.9 |
| 9:15 - 9:30 | 0 | 0 | | | 32 | 1 | 72.0 | 54.5 | | |
| 9:30 - 9:45 | 0 | 0 | | | 26 | 2 | 64.5 | 60.8 | | |
| 9:45 - 10:00 | 0 | 0 | | | 29 | 2 | 70.0 | 56.1 | | |

\* Excluding Transit Buses

16

**Table 5.**  Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520
June 21, 1995 - 6:00 AM to 10:00 AM

* Excluding Transit Buses

| MORNING PEAK Time of Day A.M. | HOV LANE * | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds (gp-hov) | Ratio (gp/hov) |
| 6:00 - 6:15 | 0 | 0 | | | 147 | 4 | 62.3 | 63.0 | | |
| 6:15 - 6:30 | 2 | 1 | 77.0 | 51.0 | 190 | 4 | 69.3 | 55.6 | -7.7 | 0.9 |
| 6:30 - 6:45 | 9 | 1 | 86.0 | 45.6 | 232 | 3 | 71.3 | 55.0 | -14.7 | 0.8 |
| 6:45 - 7:00 | 12 | 1 | 78.0 | 50.3 | 215 | 8 | 69.0 | 56.9 | -9.0 | 0.9 |
| 7:00 - 7:15 | 7 | 1 | 77.0 | 51.0 | 234 | 3 | 70.7 | 55.5 | -6.3 | 0.9 |
| 7:15 - 7:30 | 15 | 1 | 77.0 | 51.0 | 246 | 8 | 76.0 | 51.6 | -1.0 | 1.0 |
| 7:30 - 7:45 | 15 | 1 | 83.0 | 47.3 | 277 | 9 | 94.7 | 41.4 | 11.7 | 1.1 |
| 7:45 - 8:00 | 15 | 1 | 93.0 | 42.2 | 207 | 12 | 118.1 | 33.2 | 25.1 | 1.3 |
| 8:00 - 8:15 | 9 | 1 | 90.0 | 43.6 | 205 | 11 | 91.9 | 42.7 | 1.9 | 1.0 |
| 8:15 - 8:30 | 4 | 1 | 77.0 | 51.0 | 218 | 4 | 72.8 | 53.9 | -4.2 | 0.9 |
| 8:30 - 8:45 | 0 | 0 | | | 210 | 2 | 70.5 | 55.7 | | |
| 8:45 - 9:00 | 0 | 0 | | | 201 | 5 | 70.2 | 55.9 | | |
| 9:00 - 9:15 | 0 | 0 | | | 207 | 4 | 67.3 | 58.3 | | |
| 9:15 - 9:30 | 0 | 0 | | | 218 | 5 | 69.2 | 56.7 | | |
| 9:30 - 9:45 | 0 | 0 | | | 213 | 5 | 71.8 | 54.7 | | |
| 9:45 - 10:00 | 0 | 0 | | | 233 | 5 | 68.9 | 57.0 | | |

**Table 6.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane – Westbound SR-520
June 22, 1995 - 6:00 AM to 10:00 AM

| MORNING PEAK | HOV LANE * | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day A. M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds tGP-tHOV | Ratio tGP/tHOV |
| 6:00 - 6:15 | 3 | 0 | | | 174 | 2 | 70.5 | 55.7 | | |
| 6:15 - 6:30 | 1 | 1 | 54.0 | 72.7 | 180 | 2 | 68.5 | 57.3 | 14.5 | 1.3 |
| 6:30 - 6:45 | 15 | 3 | 62.7 | 62.6 | 227 | 10 | 70.1 | 56.0 | 7.4 | 1.1 |
| 6:45 - 7:00 | 11 | 2 | 71.5 | 54.9 | 228 | 22 | 68.5 | 57.3 | -3.0 | 1.0 |
| 7:00 - 7:15 | 12 | 2 | 67.5 | 58.1 | 232 | 21 | 72.9 | 53.8 | 5.4 | 1.1 |
| 7:15 - 7:30 | 22 | 2 | 72.5 | 54.1 | 252 | 20 | 93.2 | 42.1 | 20.7 | 1.3 |
| 7:30 - 7:45 | 13 | 4 | 61.5 | 63.8 | 248 | 26 | 94.6 | 41.5 | 33.1 | 1.5 |
| 7:45 - 8:00 | 18 | 3 | 48.3 | 81.2 | 187 | 21 | 74.3 | 52.8 | 26.0 | 1.5 |
| 8:00 - 8:15 | 14 | 7 | 73.7 | 53.2 | 214 | 22 | 74.9 | 52.4 | 1.2 | 1.0 |
| 8:15 - 8:30 | 6 | 3 | 93.3 | 42.1 | 191 | 21 | 76.3 | 51.4 | -17.0 | 0.8 |
| 8:30 - 8:45 | 12 | 4 | 70.8 | 55.4 | 224 | 27 | 70.4 | 55.7 | -0.4 | 1.0 |
| 8:45 - 9:00 | 11 | 5 | 75.0 | 52.3 | 190 | 26 | 68.8 | 57.0 | -6.2 | 0.9 |
| 9:00 - 9:15 | 16 | 8 | 71.1 | 55.2 | 189 | 15 | 70.1 | 56.0 | -1.0 | 1.0 |
| 9:15 - 9:30 | 12 | 5 | 70.2 | 55.9 | 214 | 26 | 69.3 | 56.6 | -0.9 | 1.0 |
| 9:30 - 9:45 | 13 | 9 | 66.7 | 58.8 | 216 | 24 | 69.8 | 56.2 | 3.1 | 1.0 |
| 9:45 - 10:00 | 17 | 10 | 63.6 | 61.7 | 205 | 20 | 69.5 | 56.5 | 5.9 | 1.1 |

\* Excluding Transit Buses

Trans|mation Systems, Inc.

**Table 7.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 19, 1995 - 3:00 PM to 7:00 PM

| EVENING PEAK Time of Day P. M. | HOV LANE* | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds $t_{GP}$-$t_{HOV}$ | Ratio $t_{GP}/t_{HOV}$ |
| 3:00 - 3:15 | 111 | 55 | 200.2 | 64.2 | 280 | 78 | 221.7 | 58.0 | 21.5 | 1.1 |
| 3:15 - 3:30 | 156 | 71 | 204.8 | 62.8 | 339 | 111 | 224.8 | 57.2 | 20.0 | 1.1 |
| 3:30 - 3:45 | 149 | 68 | 213.5 | 60.2 | 318 | 98 | 246.0 | 52.2 | 32.5 | 1.2 |
| 3:45 - 4:00 | 149 | 67 | 223.7 | 57.5 | 194 | 66 | 281.5 | 45.7 | 57.8 | 1.3 |
| 4:00 - 4:15 | 137 | 60 | 215.6 | 59.6 | 116 | 35 | 240.1 | 53.5 | 24.5 | 1.1 |
| 4:15 - 4:30 | 170 | 80 | 227.3 | 56.5 | 249 | 77 | 266.9 | 48.2 | 39.6 | 1.2 |
| 4:30 - 4:45 | 166 | 71 | 249.9 | 51.4 | 238 | 61 | 352.6 | 36.4 | 102.7 | 1.4 |
| 4:45 - 5:00 | 189 | 63 | 264.8 | 48.5 | 158 | 30 | 381.2 | 33.7 | 116.4 | 1.4 |
| 5:00 - 5:15 | 264 | 13 | 255.6 | 50.3 | 131 | 24 | 441.4 | 29.1 | 185.8 | 1.7 |
| 5:15 - 5:30 | 305 | 19 | 252.4 | 50.9 | 141 | 26 | 385.3 | 33.4 | 132.9 | 1.5 |
| 5:30 - 5:45 | 243 | 22 | 240.2 | 53.5 | 127 | 27 | 334.8 | 38.4 | 94.6 | 1.4 |
| 5:45 - 6:00 | 145 | 9 | 208.4 | 61.7 | 91 | 15 | 308.5 | 41.7 | 100.1 | 1.5 |
| 6:00 - 6:15 | 116 | 1 | 185.0 | 69.5 | 117 | 23 | 224.5 | 57.2 | 39.5 | 1.2 |
| 6:15 - 6:30 | 138 | 5 | 184.8 | 69.5 | 164 | 32 | 223.9 | 57.4 | 39.1 | 1.2 |
| 6:30 - 6:45 | 101 | 4 | 179.5 | 71.6 | 106 | 10 | 221.1 | 58.1 | 41.6 | 1.2 |
| 6:45 - 7:00 | 73 | 5 | 175.8 | 73.1 | 95 | 2 | 212.0 | 60.6 | 36.2 | 1.2 |

* Excluding Transit Buses

**Table 8.**     **Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5 June 20, 1995 - 3:00 PM to 7:00 PM**

| EVENING PEAK | HOV LANE* | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day P. M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds $t_{GP}-t_{HOV}$ | Ratio $t_{GP}/t_{HOV}$ |
| 3:00 - 3:15 | 147 | 4 | 200.0 | 64.3 | 244 | 67 | 203.5 | 63.2 | 3.5 | 1.0 |
| 3:15 - 3:30 | 161 | 7 | 216.9 | 59.3 | 258 | 56 | 237.5 | 54.1 | 20.6 | 1.1 |
| 3:30 - 3:45 | 159 | 6 | 247.3 | 52.0 | 246 | 57 | 411.4 | 31.2 | 164.1 | 1.7 |
| 3:45 - 4:00 | 207 | 9 | 277.0 | 46.4 | 266 | 71 | 585.1 | 22.0 | 308.1 | 2.1 |
| 4:00 - 4:15 | 200 | 14 | 283.4 | 45.3 | 259 | 69 | 708.2 | 18.1 | 424.8 | 2.5 |
| 4:15 - 4:30 | 247 | 22 | 337.9 | 38.0 | 270 | 77 | 788.2 | 16.3 | 450.3 | 2.3 |
| 4:30 - 4:45 | 230 | 13 | 354.9 | 36.2 | 256 | 70 | 940.6 | 13.7 | 585.7 | 2.7 |
| 4:45 - 5:00 | 313 | 1 | 465.0 | 27.6 | 230 | 2 | 960.0 | 13.4 | 495.0 | 2.1 |
| 5:00 - 5:15 | 239 | 96 | 494.0 | 26.0 | 326 | 68 | 938.4 | 13.7 | 444.4 | 1.9 |
| 5:15 - 5:30 | 313 | 137 | 524.3 | 24.5 | 339 | 83 | 981.3 | 13.1 | 457.0 | 1.9 |
| 5:30 - 5:45 | 275 | 107 | 524.5 | 24.5 | 351 | 81 | 953.6 | 13.5 | 429.1 | 1.8 |
| 5:45 - 6:00 | 283 | 102 | 485.4 | 26.5 | 369 | 76 | 1007.6 | 12.8 | 522.2 | 2.1 |
| 6:00 - 6:15 | 216 | 73 | 478.8 | 26.8 | 334 | 77 | 936.8 | 13.7 | 458.0 | 2.0 |
| 6:15 - 6:30 | 214 | 93 | 271.9 | 47.3 | 336 | 66 | 692.4 | 18.6 | 420.5 | 2.5 |
| 6:30 - 6:45 | 80 | 35 | 203.7 | 63.1 | 282 | 29 | 382.2 | 33.6 | 178.5 | 1.9 |
| 6:45 - 7:00 | 76 | 17 | 172.2 | 74.6 | 269 | 50 | 229.7 | 56.0 | 57.5 | 1.3 |

* Excluding Transit Buses

**Table 9.** **Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5**
**June 21, 1995 - 3:00 PM to 7:00 PM**

| EVENING PEAK Time of Day P. M. | HOV LANE* | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds $t_{GP}$-$t_{HOV}$ | Ratio $t_{GP}/t_{HOV}$ |
| 3:00 - 3:15 | 49 | 10 | 208.1 | 61.8 | 226 | 11 | 207.9 | 61.8 | -0.2 | 1.0 |
| 3:15 - 3:30 | 57 | 14 | 210.1 | 61.2 | 284 | 16 | 221.3 | 58.1 | 11.2 | 1.1 |
| 3:30 - 3:45 | 66 | 17 | 234.3 | 54.9 | 282 | 15 | 345.9 | 37.2 | 111.6 | 1.5 |
| 3:45 - 4:00 | 77 | 19 | 272.0 | 47.3 | 290 | 13 | 493.8 | 26.0 | 221.8 | 1.8 |
| 4:00 - 4:15 | 76 | 16 | 305.3 | 42.1 | 235 | 7 | 497.8 | 25.8 | 192.5 | 1.6 |
| 4:15 - 4:30 | 103 | 22 | 327.5 | 39.2 | 274 | 16 | 640.4 | 20.1 | 312.9 | 2.0 |
| 4:30 - 4:45 | 83 | 20 | 371.7 | 34.6 | 275 | 7 | 719.1 | 17.9 | 347.4 | 1.9 |
| 4:45 - 5:00 | 60 | 6 | 408.3 | 31.5 | 41 | 12 | 714.2 | 18.0 | 305.9 | 1.7 |
| 5:00 - 5:15 | 89 | 7 | 378.1 | 34.0 | 271 | 56 | 703.3 | 18.3 | 325.2 | 1.9 |
| 5:15 - 5:30 | 81 | 10 | 318.1 | 40.4 | 283 | 71 | 711.3 | 18.1 | 393.2 | 2.2 |
| 5:30 - 5:45 | 85 | 10 | 323.3 | 39.8 | 251 | 65 | 617.6 | 20.8 | 294.3 | 1.9 |
| 5:45 - 6:00 | 49 | 5 | 295.4 | 43.5 | 267 | 46 | 558.7 | 23.0 | 263.3 | 1.9 |
| 6:00 - 6:15 | 48 | 2 | 273.0 | 47.1 | 243 | 23 | 332.6 | 38.6 | 59.6 | 1.2 |
| 6:15 - 6:30 | 37 | 2 | 267.5 | 48.0 | 223 | 40 | 341.8 | 37.6 | 74.3 | 1.3 |
| 6:30 - 6:45 | 24 | 4 | 229.0 | 56.1 | 212 | 43 | 393.7 | 32.6 | 164.7 | 1.7 |
| 6:45 - 7:00 | 28 | 2 | 224.0 | 57.4 | 193 | 18 | 229.4 | 56.0 | 5.4 | 1.0 |

* Excluding Transit Buses

**Table 10.**    Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 22, 1995 - 3:00 PM to 7:00 PM

| EVENING PEAK<br>Time of Day<br>P. M. | HOV LANE* | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Seconds $t_{GP} - t_{HOV}$ | Ratio $t_{GP}/t_{HOV}$ |
| 3:00 - 3:15 | 128 | 53 | 205.4 | 62.6 | 263 | 77 | 213.8 | 60.1 | 8.4 | 1.0 |
| 3:15 - 3:30 | 156 | 62 | 220.3 | 58.3 | 271 | 69 | 247.4 | 51.9 | 27.1 | 1.1 |
| 3:30 - 3:45 | 185 | 90 | 245.7 | 52.3 | 277 | 73 | 353.9 | 36.3 | 108.2 | 1.4 |
| 3:45 - 4:00 | 201 | 74 | 272.2 | 47.2 | 294 | 81 | 484.9 | 26.5 | 212.7 | 1.8 |
| 4:00 - 4:15 | 211 | 85 | 318.8 | 40.3 | 259 | 69 | 650.4 | 19.8 | 331.6 | 2.0 |
| 4:15 - 4:30 | 229 | 85 | 307.5 | 41.8 | 265 | 58 | 638.6 | 20.1 | 331.1 | 2.1 |
| 4:30 - 4:45 | 220 | 87 | 333.2 | 38.6 | 270 | 66 | 607.3 | 21.2 | 274.1 | 1.8 |
| 4:45 - 5:00 | 272 | 52 | 363.7 | 35.3 | 218 | 24 | 566.5 | 22.7 | 202.8 | 1.6 |
| 5:00 - 5:15 | 195 | 67 | 392.7 | 32.7 | 312 | 76 | 612.6 | 21.0 | 219.9 | 1.6 |
| 5:15 - 5:30 | 251 | 77 | 362.4 | 35.5 | 346 | 68 | 671.1 | 19.2 | 308.7 | 1.9 |
| 5:30 - 5:45 | 188 | 48 | 330.9 | 38.8 | 312 | 55 | 686.2 | 18.7 | 355.3 | 2.1 |
| 5:45 - 6:00 | 190 | 57 | 284.9 | 45.1 | 333 | 60 | 526.1 | 24.4 | 241.2 | 1.8 |
| 6:00 - 6:15 | 167 | 42 | 286.7 | 44.8 | 297 | 48 | 473.3 | 27.2 | 186.6 | 1.7 |
| 6:15 - 6:30 | 144 | 38 | 230.3 | 55.8 | 317 | 52 | 294.9 | 43.6 | 64.6 | 1.3 |
| 6:30 - 6:45 | 107 | 39 | 199.9 | 64.3 | 292 | 69 | 207.9 | 61.8 | 8.0 | 1.0 |
| 6:45 - 7:00 | 91 | 22 | 203.2 | 63.2 | 233 | 53 | 209.2 | 61.4 | 6.0 | 1.0 |

* Excluding Transit Buses

**Table 11.** **Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Westbound SR-520 June 19 Through June 22, 1995 - 6:00 AM to 10:00 AM**

| MORNING PEAK | HOV LANE* | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day A.M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Avg. Seconds $t_{GP}$-$t_{HOV}$ | Avg. Ratio $t_{GP}/t_{HOV}$ |
| 6:00 - 6:15 | 6 | 0 | | | 568 | 26 | 64.5 | 60.8 | | |
| 6:15 - 6:30 | 13 | 4 | 65.0 | 60.4 | 753 | 53 | 67.5 | 58.1 | 2.5 | 1.0 |
| 6:30 - 6:45 | 36 | 9 | 68.8 | 57.0 | 895 | 47 | 68.7 | 57.1 | -0.1 | 1.0 |
| 6:45 - 7:00 | 37 | 5 | 71.6 | 54.8 | 862 | 75 | 67.8 | 57.9 | -3.8 | 0.9 |
| 7:00 - 7:15 | 35 | 4 | 63.5 | 61.8 | 938 | 67 | 69.8 | 56.2 | 6.3 | 1.1 |
| 7:15 - 7:30 | 54 | 11 | 66.3 | 59.2 | 1,019 | 79 | 78.9 | 49.7 | 12.6 | 1.2 |
| 7:30 - 7:45 | 52 | 10 | 63.7 | 61.6 | 1,044 | 97 | 97.9 | 40.1 | 34.2 | 1.5 |
| 7:45 - 8:00 | 57 | 6 | 61.9 | 63.4 | 805 | 76 | 100.7 | 39.0 | 38.8 | 1.6 |
| 8:00 - 8:15 | 22 | 9 | 78.9 | 49.7 | 657 | 57 | 88.8 | 44.2 | 9.9 | 1.1 |
| 8:15 - 8:30 | 25 | 6 | 82.3 | 47.7 | 663 | 43 | 111.0 | 35.4 | 28.7 | 1.3 |
| 8:30 - 8:45 | 28 | 7 | 78.6 | 49.9 | 658 | 39 | 111.2 | 35.3 | 32.6 | 1.4 |
| 8:45 - 9:00 | 23 | 7 | 81.7 | 48.0 | 627 | 48 | 90.8 | 43.2 | 9.1 | 1.1 |
| 9:00 - 9:15 | 30 | 10 | 76.7 | 51.2 | 630 | 42 | 70.9 | 55.3 | -5.8 | 0.9 |
| 9:15 - 9:30 | 15 | 6 | 68.6 | 57.2 | 643 | 46 | 69.3 | 56.6 | 0.7 | 1.0 |
| 9:30 - 9:45 | 13 | 6 | 66.7 | 58.8 | 694 | 61 | 69.1 | 56.8 | 2.4 | 1.0 |
| 9:45 - 10:00 | 17 | 10 | 63.6 | 61.7 | 661 | 41 | 68.7 | 57.1 | 5.1 | 1.1 |

* Excluding Transit Buses

* Excluding Transit Buses

| EVENING PEAK Time of Day P.M. | HOV LANE* | | | | GENERAL PURPOSE LANE | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Average Speed (mph) | Avg. Seconds (Gr.P./HOV) | Avg. Ratio (Gr.P./HOV) |
| 3:00 - 3:15 | 435 | 122 | 203.4 | 63.2 | 1,013 | 233 | 211.7 | 60.7 | 8.3 | 1.0 |
| 3:15 - 3:30 | 530 | 154 | 213.0 | 60.3 | 1,152 | 252 | 232.3 | 55.3 | 19.3 | 1.1 |
| 3:30 - 3:45 | 559 | 101 | 235.2 | 54.6 | 1,123 | 243 | 339.3 | 37.9 | 104.1 | 1.4 |
| 3:45 - 4:00 | 634 | 169 | 261.2 | 49.2 | 1,044 | 231 | 461.3 | 27.9 | 200.1 | 1.8 |
| 4:00 - 4:15 | 624 | 175 | 280.8 | 45.8 | 868 | 180 | 524.1 | 24.5 | 243.3 | 1.9 |
| 4:15 - 4:30 | 749 | 209 | 300.1 | 42.8 | 1,058 | 228 | 583.5 | 22.0 | 283.4 | 1.9 |
| 4:30 - 4:45 | 669 | 191 | 347.7 | 37.0 | 1,039 | 204 | 654.9 | 19.6 | 307.2 | 1.9 |
| 4:45 - 5:00 | 834 | 122 | 375.5 | 34.2 | 647 | 122 | 655.5 | 19.6 | 280.0 | 1.7 |
| 5:00 - 5:15 | 787 | 183 | 380.1 | 33.8 | 1,040 | 224 | 673.9 | 19.1 | 293.8 | 1.8 |
| 5:15 - 5:30 | 950 | 243 | 364.3 | 35.3 | 1,109 | 248 | 687.2 | 18.7 | 322.9 | 1.9 |
| 5:30 - 5:45 | 791 | 178 | 354.7 | 36.2 | 1,041 | 228 | 648.1 | 19.8 | 293.4 | 1.8 |
| 5:45 - 6:00 | 667 | 173 | 318.5 | 40.4 | 1,060 | 197 | 600.2 | 21.4 | 281.7 | 1.9 |
| 6:00 - 6:15 | 547 | 118 | 305.9 | 42.0 | 991 | 171 | 491.8 | 26.1 | 185.9 | 1.6 |
| 6:15 - 6:30 | 533 | 138 | 238.6 | 53.9 | 1,040 | 190 | 388.3 | 33.1 | 149.7 | 1.6 |
| 6:30 - 6:45 | 312 | 82 | 203.0 | 63.3 | 892 | 151 | 301.2 | 42.7 | 98.2 | 1.5 |
| 6:45 - 7:00 | 268 | 46 | 193.8 | 66.3 | 790 | 123 | 220.1 | 58.4 | 26.3 | 1.1 |

Table 12.    Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Northbound I-5
June 19 thru June 22, 1995 - 3:00 PM to 7:00 PM

## 5.0    CONCLUSIONS

Results indicate the evening peak period commute home from downtown Seattle on northbound I-5 can be 2.0 to 2.7 times longer in high volume traffic conditions than the same commute using the HOV facilities for the ~3 ½ miles of freeway monitored. Results averaged over the four weekdays for the entire four hour evening period indicate approximately 60% longer commute times in the general purpose versus HOV lanes.

Similar results could not be statistically verified for the morning peak period on westbound SR-520 due to the relatively low number of vehicles observed using the HOV facilities during the survey period. However, there was evidence of approximately 50% longer commute times in the general purpose traffic lanes between 7:30 - 8:00 AM than the vehicles observed in the HOV lane on SR-520 for the ~1 mile of freeway monitored.

Average speeds of traffic flow in the general purpose lane ranged from a high of 60 mph during non-congested periods to as low as 19 mph during periods of heavy congestion with stop-and-go traffic. Average speeds of traffic flow in the HOV lane ranged from a high of 66 mph to a low of 34 mph.

Automatic video-based license plate reading techniques were successful in determining travel time data for both peak traffic periods at separate study locations by collecting and analyzing over 90,000 vehicle license plates (approximately 75% of traffic flow) using a machine vision system which operated on video tapes of vehicles passing by each of four (4) camera stations located strategically along the travel corridor during peak hours. This license plate data was used to "match" vehicles between camera stations and compute travel times on more than 200 vehicles per hour in high volume traffic conditions.

Transmation
*Systems, Inc.*

## 6.0    APPENDIX

**List of Tables Summarizing Mean Travel Times and Statistical Variations**

**List of Tables Summarizing Travel Time Matching Data Between Camera Stations**

**List of Tables Summarizing License Plate Numbers Matched to Station and Time**

**Table 3A.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
June 19, 1995 - 6:00 AM to 10:00 AM

| MORNING PEAK Time of Day A.M. | HOV LANE * | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds $t_g - t_b$ | Ratio $t_g/t_b$ |
| 6:00 - 6:15 | 3 | 0 | | | | 76 | 4 | 62.8 | 4.1 | 6.5 | | |
| 6:15 - 6:30 | 7 | 1 | 52.0 | | | 192 | 23 | 66.6 | 3.4 | 5.1 | 14.6 | 1.3 |
| 6:30 - 6:45 | 8 | 4 | 53.5 | 2.4 | 4.5 | 209 | 21 | 66.5 | 3.3 | 5.0 | 13.0 | 1.2 |
| 6:45 - 7:00 | 8 | 1 | 51.0 | | | 215 | 19 | 67.2 | 4.0 | 6.0 | 16.2 | 1.3 |
| 7:00 - 7:15 | 16 | 2 | 46.0 | 4.2 | 9.1 | 237 | 16 | 70.9 | 3.9 | 5.5 | 24.9 | 1.5 |
| 7:15 - 7:30 | 17 | 8 | 49.3 | 6.8 | 13.8 | 268 | 31 | 73.3 | 4.0 | 5.5 | 24.0 | 1.5 |
| 7:30 - 7:45 | 24 | 5 | 46.6 | 4.8 | 10.3 | 251 | 33 | 86.2 | 15.8 | 18.3 | 39.6 | 1.8 |
| 7:45 - 8:00 | 24 | 2 | 44.5 | 4.9 | 11.0 | 200 | 29 | 77.1 | 13.4 | 17.4 | 32.6 | 1.7 |
| 8:00 - 8:15 | 2 | 1 | 73.0 | | | 211 | 22 | 73.3 | 5.4 | 7.4 | 0.3 | 1.0 |
| 8:15 - 8:30 | 2 | 1 | 74.0 | | | 212 | 17 | 70.0 | 4.0 | 5.5 | - 4.0 | 0.95 |
| 8:30 - 8:45 | 3 | 1 | 72.0 | | | 195 | 8 | 68.0 | 1.9 | 2.8 | - 4.0 | 0.94 |
| 8:45 - 9:00 | 2 | 1 | 74.0 | | | 201 | 15 | 66.3 | 4.2 | 6.3 | - 7.7 | 0.90 |
| 9.00 - 9:15 | 4 | 1 | 68.0 | | | 205 | 22 | 65.1 | 3.8 | 5.8 | - 2.9 | 0.96 |
| 9:15 - 9:30 | 3 | 1 | 67.0 | | | 179 | 14 | 66.6 | 3.3 | 5.0 | - 0.4 | 0.99 |
| 9:30 - 9:45 | | | | | | 239 | 30 | 70.2 | 4.3 | 6.1 | | |
| 9:45 - 10:00 | | | | | | 194 | 14 | 66.4 | 3.3 | 5.0 | | |

* Excluding Transit Buses

27

Transformation Systems, Inc.

Transformation Systems, Inc.

* Excluding Transit Buses

**Table 4A.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
June 20, 1995 - 6:00 AM to 10:00 AM

| MORNING PEAK Time of Day A.M. | HOV LANE * | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds t'-t | Ratio t'/t |
| 6:00 - 6:15 | 0 | 0 | | | | 171 | 16 | 62.2 | 2.6 | 4.2% | | |
| 6:15 - 6:30 | 3 | 1 | 75.0 | | | 191 | 24 | 65.5 | 3.7 | 5.6% | - 9.5 | 0.87 |
| 6:30 - 6:45 | 4 | 1 | 73.0 | | | 227 | 13 | 66.8 | 3.2 | 4.8% | - 6.2 | 0.92 |
| 6:45 - 7:00 | 9 | 1 | 98.0 | | | 204 | 26 | 66.3 | 3.6 | 5.4% | - 19.7 | 0.77 |
| 7:00 - 7:15 | 0 | 0 | | | | 235 | 24 | 68.3 | 4.3 | 6.3% | | |
| 7:15 - 7:30 | 0 | 0 | | | | 253 | 20 | 73.4 | 4.8 | 6.5% | | |
| 7:30 - 7:45 | 0 | 0 | | | | 268 | 29 | 116.3 | 22.2 | 19.1% | | |
| 7:45 - 8:00 | 0 | 0 | | | | 211 | 14 | 133.1 | 18.2 | 13.7% | | |
| 8:00 - 8:15 | 0 | 0 | | | | 27 | 2 | 115.0 | 4.2 | 3.7% | | |
| 8:15 - 8:30 | 10 | 1 | 85.0 | | | 42 | 1 | 225.0 | | | 140.0 | 2.6 |
| 8:30 - 8:45 | 13 | 2 | 93.0 | 2.8 | | 29 | 2 | 236.0 | 35.4 | 15.0% | 143.0 | 2.5 |
| 8:45 - 9:00 | 10 | 1 | 196.0 | | | 35 | 1 | 158.0 | | | - 38.0 | 0.81 |
| 9:00 - 9:15 | 10 | 1 | 91.0 | | | 29 | 1 | 81.0 | | | - 10.0 | 0.89 |
| 9:15 - 9:30 | 0 | 0 | | | | 32 | 1 | 72.0 | | | | |
| 9:30 - 9:45 | 0 | 0 | | | | 26 | 2 | 64.5 | 0.7 | 1.1% | | |
| 9:45 - 10:00 | 0 | 0 | | | | 29 | 2 | 70.0 | 4.2 | 6.0% | | |

**Table 5A.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
June 21, 1995 - 6:00 AM to 10:00 AM

| MORNING PEAK Time of Day A.M. | HOV LANE * # of License Plates | # Of Matched Pairs | Mean Travel Time (sec) | Std Deviation (sec) | C.V. of Variance (%) | GENERAL PURPOSE LANE # of License Plates | # Of Matched Pairs | Mean Travel Time (sec) | Std Deviation (sec) | C.V. of Variance (%) | TRAVEL TIME DIFFERENCES $t_2-t_1$ Seconds | $t_2/t_1$ Ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6:00 - 6:15 | 0 | 0 | | | | 147 | 4 | 62.3 | 3.2 | 5.1% | | |
| 6:15 - 6:30 | 2 | 1 | 77.0 | | | 190 | 4 | 69.3 | 0.5 | 0.7% | - 7.7 | 0.90 |
| 6:30 - 6:45 | 6 | 1 | 86.0 | | | 232 | 3 | 71.3 | 1.5 | 2.1% | - 14.7 | 0.83 |
| 6:45 - 7:00 | 12 | 1 | 78.0 | | | 215 | 8 | 69.0 | 4.2 | 6.1% | - 9.0 | 0.88 |
| 7:00 - 7:15 | 7 | 1 | 77.0 | | | 234 | 3 | 70.7 | 1.5 | 2.1% | - 6.3 | 0.92 |
| 7:15 - 7:30 | 15 | 1 | 77.0 | | | 246 | 8 | 76.0 | 1.3 | 1.7% | - 1.0 | 0.99 |
| 7:30 - 7:45 | 15 | 1 | 83.0 | | | 277 | 9 | 94.7 | 15.9 | 16.8% | 11.7 | 1.1 |
| 7:45 - 8:00 | 15 | 1 | 93.0 | | | 207 | 12 | 118.1 | 12.5 | 10.6% | 25.1 | 1.3 |
| 8:00 - 8:15 | 9 | 1 | 90.0 | | | 205 | 11 | 91.9 | 21.4 | 23.3% | 1.9 | 1.0 |
| 8:15 - 8:30 | 4 | 1 | 77.0 | | | 218 | 4 | 72.8 | 4.1 | 5.6% | - 4.2 | 0.95 |
| 8:30 - 8:45 | 0 | 0 | | | | 210 | 2 | 70.5 | 3.5 | 5.0% | | |
| 8:45 - 9:00 | 0 | 0 | | | | 201 | 5 | 70.2 | 1.5 | 2.1% | | |
| 9:00 - 9:15 | 0 | 0 | | | | 207 | 4 | 67.3 | 4.1 | 6.1% | | |
| 9:15 - 9:30 | 0 | 0 | | | | 218 | 5 | 69.2 | 2.6 | 3.8% | | |
| 9:30 - 9:45 | 0 | 0 | | | | 213 | 5 | 71.8 | 1.6 | 2.2% | | |
| 9:45 - 10:00 | 0 | 0 | | | | 233 | 5 | 68.8 | 1.9 | 2.8% | | |

* Excluding Transit Buses

Transformation Systems, Inc.

* Excluding Transit Buses

| MORNING PEAK | HOV LANE * | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day A.M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds $t_2-t_1$ | Ratio $t_2/t_1$ |
| 6:00 - 6:15 | 3 | 0 | | | | 174 | 2 | 70.5 | 9.2 | 13.1% | | |
| 6:15 - 6:30 | 1 | 1 | 54.0 | | | 180 | 2 | 68.5 | 3.5 | 5.1% | 14.5 | 1.3 |
| 6:30 - 6:45 | 15 | 3 | 62.7 | 2.5 | 4.0% | 227 | 10 | 70.1 | 3.3 | 4.7% | 7.4 | 1.1 |
| 6:45 - 7:00 | 11 | 2 | 71.5 | 12.0 | 16.8% | 228 | 22 | 68.5 | 4.4 | 6.4% | -3.0 | 0.96 |
| 7:00 - 7:15 | 12 | 2 | 67.5 | 0.7 | 1.0% | 232 | 21 | 72.9 | 6.3 | 8.6% | 5.4 | 1.1 |
| 7:15 - 7:30 | 22 | 2 | 72.5 | 30.4 | 41.9% | 252 | 20 | 93.2 | 15.5 | 16.6% | 20.7 | 1.3 |
| 7:30 - 7:45 | 13 | 4 | 61.5 | 3.5 | 5.7% | 248 | 26 | 94.6 | 13.5 | 14.3% | 33.1 | 1.5 |
| 7:45 - 8:00 | 18 | 3 | 48.3 | 0.6 | 1.2% | 187 | 21 | 74.3 | 7.6 | 10.2% | 26.0 | 1.5 |
| 8:00 - 8:15 | 14 | 7 | 73.7 | 5.9 | 8.0% | 214 | 22 | 74.9 | 5.8 | 7.7% | 1.2 | 1.0 |
| 8:15 - 8:30 | 9 | 3 | 93.3 | 8.1 | 8.7% | 191 | 21 | 76.3 | 8.8 | 11.5% | -17.0 | 0.82 |
| 8:30 - 8:45 | 12 | 4 | 70.8 | 2.1 | 3.0% | 224 | 27 | 70.4 | 3.8 | 5.4% | 0.4 | 0.99 |
| 8:45 - 9:00 | 11 | 5 | 75.0 | 4.3 | 5.7% | 190 | 26 | 68.8 | 4.5 | 6.5% | -6.2 | 0.92 |
| 9:00 - 9:15 | 16 | 8 | 71.1 | 3.4 | 4.8% | 189 | 15 | 70.1 | 4.8 | 6.8% | -1.0 | 0.99 |
| 9:15 - 9:30 | 12 | 5 | 70.2 | 5.1 | 7.3% | 214 | 26 | 69.3 | 4.5 | 6.5% | -0.9 | 0.99 |
| 9:30 - 9:45 | 13 | 9 | 66.7 | 2.0 | 3.0% | 216 | 24 | 69.8 | 3.7 | 5.3% | 3.1 | 1.0 |
| 9:45 - 10:00 | 17 | 10 | 63.6 | 4.2 | 6.6% | 205 | 20 | 69.5 | 3.9 | 5.6% | 5.9 | 1.1 |

Table 6A.  Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - State Route 520
June 22, 1995 - 6:00 AM to 10:00 AM

Transformation Systems, Inc.

* Excluding Transit Buses

**Table 7A.**   Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane – Interstate 5
June 19, 1995 - 3:00 PM to 7:00 PM

| EVENING PEAK P.M. | HOV LANE* | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day P.M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds $t_g$-$t_h$ | Ratio $t_g$/$t_h$ |
| 3:00 - 3:15 | 111 | 55 | 200.2 | 7.6 | 3.8% | 280 | 78 | 221.7 | 6.6 | 3.0% | 21.5 | 1.1 |
| 3:15 - 3:30 | 156 | 71 | 204.8 | 6.8 | 3.3% | 339 | 111 | 224.8 | 7.9 | 3.5% | 20.0 | 1.1 |
| 3:30 - 3:45 | 149 | 68 | 213.5 | 8.0 | 3.7% | 318 | 86 | 246.0 | 16.0 | 6.5% | 32.5 | 1.2 |
| 3:45 - 4:00 | 149 | 67 | 223.7 | 7.1 | 3.2% | 194 | 66 | 281.5 | 19.2 | 6.8% | 57.8 | 1.3 |
| 4:00 - 4:15 | 137 | 60 | 215.6 | 6.7 | 3.1% | 116 | 35 | 240.1 | 5.4 | 2.2% | 24.5 | 1.1 |
| 4:15 - 4:30 | 170 | 80 | 227.3 | 10.5 | 4.6% | 249 | 77 | 266.9 | 20.7 | 7.8% | 39.6 | 1.2 |
| 4:30 - 4:45 | 166 | 71 | 249.9 | 11.5 | 4.6% | 238 | 61 | 352.6 | 21.8 | 6.2% | 102.7 | 1.4 |
| 4:45 - 5:00 | 189 | 63 | 264.8 | 13.7 | 5.2% | 158 | 30 | 381.2 | 17.8 | 4.7% | 116.4 | 1.4 |
| 5:00 - 5:15 | 264 | 13 | 255.6 | 21.5 | 8.4% | 131 | 24 | 441.4 | 15.0 | 3.4% | 185.8 | 1.7 |
| 5:15 - 5:30 | 305 | 19 | 252.4 | 20.8 | 8.2% | 141 | 26 | 385.3 | 16.1 | 4.2% | 132.9 | 1.5 |
| 5:30 - 5:45 | 243 | 22 | 240.2 | 27.2 | 11.3% | 127 | 27 | 334.8 | 23.3 | 7.0% | 94.6 | 1.4 |
| 5:45 - 6:00 | 145 | 9 | 208.4 | 7.3 | 3.5% | 91 | 15 | 308.5 | 25.5 | 8.3% | 100.1 | 1.5 |
| 6:00 - 6:15 | 116 | 1 | 185.0 | | 0.0% | 117 | 23 | 224.5 | 6.6 | 2.9% | 39.5 | 1.2 |
| 6:15 - 6:30 | 138 | 5 | 184.8 | 5.1 | 2.8% | 164 | 32 | 223.9 | 6.8 | 3.0% | 39.1 | 1.2 |
| 6:30 - 6:45 | 101 | 4 | 179.5 | 4.5 | 2.5% | 106 | 10 | 221.1 | 7.0 | 3.2% | 41.6 | 1.2 |
| 6:45 - 7:00 | 73 | 5 | 175.8 | 10.9 | 6.2% | 95 | 2 | 212.0 | 1.4 | 0.7% | 36.2 | 1.2 |

*Transformation Systems, Inc.*

**Table 8A.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5
June 20, 1995 - 3:00 PM to 7:00 PM

* Excluding Transit Buses

| EVENING PEAK | HOV LANE* | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day P.M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds "+" "-" | Ratio "+"/"-" |
| 3:00 - 3:15 | 147 | 4 | 200.0 | 12.3 | 6.2% | 244 | 67 | 203.5 | 6.4 | 3.1% | 3.5 | 1.0 |
| 3:15 - 3:30 | 161 | 7 | 216.9 | 8.4 | 3.9% | 258 | 56 | 237.5 | 25.5 | 10.7% | 20.6 | 1.1 |
| 3:30 - 3:45 | 159 | 6 | 247.3 | 17.7 | 7.2% | 246 | 57 | 411.4 | 55.5 | 13.5% | 164.1 | 1.7 |
| 3:45 - 4:00 | 207 | 9 | 277.0 | 20.6 | 7.4% | 266 | 71 | 585.1 | 77.0 | 13.2% | 308.1 | 2.1 |
| 4:00 - 4:15 | 200 | 14 | 283.4 | 9.2 | 3.2% | 259 | 69 | 708.2 | 41.8 | 5.9% | 424.8 | 2.5 |
| 4:15 - 4:30 | 247 | 22 | 337.9 | 17.7 | 5.2% | 270 | 77 | 788.2 | 60.8 | 7.7% | 450.3 | 2.3 |
| 4:30 - 4:45 | 230 | 13 | 354.9 | 33.5 | 9.4% | 256 | 70 | 940.6 | 43.7 | 4.6% | 585.7 | 2.7 |
| 4:45 - 5:00 | 313 | 1 | 465.0 | | | 230 | 2 | 960.0 | 2.1 | 0.2% | 495.0 | 2.1 |
| 5:00 - 5:15 | 239 | 96 | 494.0 | 48.2 | 9.8% | 326 | 68 | 938.4 | 50.0 | 5.3% | 444.4 | 1.9 |
| 5:15 - 5:30 | 313 | 137 | 524.3 | 40.0 | 7.6% | 339 | 83 | 981.3 | 22.3 | 2.3% | 457.0 | 1.9 |
| 5:30 - 5:45 | 275 | 107 | 524.5 | 40.6 | 7.7% | 351 | 81 | 953.6 | 72.6 | 7.6% | 429.1 | 1.8 |
| 5:45 - 6:00 | 283 | 102 | 485.4 | 32.8 | 6.8% | 369 | 76 | 1007.6 | 57.1 | 5.7% | 522.2 | 2.1 |
| 6:00 - 6:15 | 216 | 73 | 478.8 | 91.2 | 19.0% | 334 | 77 | 936.8 | 63.6 | 6.8% | 458.0 | 2.0 |
| 6:15 - 6:30 | 214 | 93 | 271.9 | 41.4 | 15.2% | 336 | 66 | 692.4 | 86.3 | 12.5% | 420.5 | 2.5 |
| 6:30 - 6:45 | 80 | 35 | 203.7 | 16.3 | 8.0% | 282 | 29 | 382.2 | 87.7 | 22.9% | 178.5 | 1.9 |
| 6:45 - 7:00 | 76 | 17 | 172.2 | 6.6 | 3.8% | 269 | 50 | 229.7 | 21.8 | 9.5% | 57.5 | 1.3 |

**Table 9A.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5
June 21, 1995 - 3:00 PM to 7:00 PM

| EVENING PEAK | HOV LANE* | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day P.M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds $t_g - t_h$ | Ratio $t_g / t_h$ |
| 3:00 - 3:15 | 49 | 10 | 208.1 | 6.3 | 3.0% | 226 | 11 | 207.9 | 7.0 | 3.4% | - 0.2 | 1.0 |
| 3:15 - 3:30 | 57 | 14 | 210.1 | 6.5 | 3.1% | 284 | 16 | 221.3 | 11.6 | 5.2% | 11.2 | 1.1 |
| 3:30 - 3:45 | 66 | 17 | 234.3 | 13.7 | 5.8% | 282 | 15 | 345.9 | 64.4 | 18.6% | 111.6 | 1.5 |
| 3:45 - 4:00 | 77 | 19 | 272.0 | 35.8 | 13.2% | 290 | 13 | 493.8 | 73.3 | 14.8% | 221.8 | 1.8 |
| 4:00 - 4:15 | 76 | 16 | 305.3 | 45.6 | 14.9% | 235 | 7 | 497.8 | 46.7 | 9.4% | 192.5 | 1.6 |
| 4:15 - 4:30 | 103 | 22 | 327.5 | 15.4 | 4.7% | 274 | 16 | 640.4 | 55.3 | 8.6% | 312.9 | 2.0 |
| 4:30 - 4:45 | 83 | 20 | 371.7 | 11.6 | 3.1% | 275 | 7 | 719.1 | 37.5 | 5.2% | 347.4 | 1.9 |
| 4:45 - 5:00 | 60 | 6 | 408.3 | 12.3 | 3.0% | 41 | 12 | 714.2 | 7.6 | 1.1% | 305.9 | 1.7 |
| 5:00 - 5:15 | 89 | 7 | 378.1 | 31.3 | 8.3% | 271 | 56 | 703.3 | 36.3 | 5.2% | 325.2 | 1.9 |
| 5:15 - 5:30 | 81 | 10 | 318.1 | 25.8 | 8.1% | 283 | 71 | 711.3 | 78.5 | 11.0% | 393.2 | 2.2 |
| 5:30 - 5:45 | 85 | 10 | 323.3 | 39.8 | 12.3% | 251 | 65 | 617.6 | 34.5 | 5.6% | 294.3 | 1.9 |
| 5:45 - 6:00 | 49 | 5 | 295.4 | 33.2 | 11.2% | 267 | 46 | 558.7 | 85.9 | 15.4% | 263.3 | 1.9 |
| 6:00 - 6:15 | 48 | 2 | 273.0 | 30.0 | 11.0% | 243 | 23 | 332.6 | 65.1 | 19.6% | 59.6 | 1.2 |
| 6:15 - 6:30 | 37 | 2 | 267.5 | 85.6 | 32.0% | 223 | 40 | 341.8 | 97.4 | 28.5% | 74.3 | 1.3 |
| 6:30 - 6:45 | 24 | 4 | 229.0 | 3.2 | 1.4% | 212 | 43 | 393.7 | 58.4 | 14.8% | 164.7 | 1.7 |
| 6:45 - 7:00 | 28 | 2 | 224.0 | 5.7 | 2.5% | 193 | 18 | 229.4 | 43.7 | 19.1% | 5.4 | 1.0 |

* Excluding Transit Buses

**Table 10A.** Comparison of Mean Travel Times on HOV Lane and Adjacent General Purpose Lane - Interstate 5
June 22, 1995 - 3:00 PM to 7:00 PM

| EVENING PEAK | HOV LANE* | | | | | GENERAL PURPOSE LANE | | | | | TRAVEL TIME DIFFERENCES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time of Day P.M. | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | # of License Plates | # of Matched Pairs | Mean Travel Time (sec) | Std. Deviation (sec) | C.V. of Variance (%) | Seconds $t_g - t_h$ | Ratio $t_g / t_h$ |
| 3:00 - 3:15 | 128 | 53 | 205.4 | 9.0 | 4.4% | 263 | 77 | 213.8 | 6.2 | 2.9% | 8.4 | 1.0 |
| 3:15 - 3:30 | 156 | 62 | 220.3 | 17.6 | 8.0% | 271 | 69 | 247.4 | 34.1 | 13.8% | 27.1 | 1.1 |
| 3:30 - 3:45 | 185 | 90 | 245.7 | 11.0 | 4.5% | 277 | 73 | 353.9 | 37.6 | 10.6% | 108.2 | 1.4 |
| 3:45 - 4:00 | 201 | 74 | 272.2 | 13.1 | 4.8% | 294 | 81 | 484.9 | 43.9 | 9.1% | 212.7 | 1.8 |
| 4:00 - 4:15 | 211 | 85 | 318.8 | 26.2 | 8.2% | 259 | 69 | 650.4 | 60.8 | 9.3% | 331.6 | 2.0 |
| 4:15 - 4:30 | 229 | 85 | 307.5 | 45.9 | 14.9% | 265 | 58 | 638.6 | 41.9 | 6.6% | 331.1 | 2.1 |
| 4:30 - 4:45 | 220 | 87 | 333.2 | 24.8 | 7.4% | 270 | 66 | 607.3 | 40.7 | 6.7% | 274.1 | 1.8 |
| 4:45 - 5:00 | 272 | 52 | 363.7 | 13.7 | 3.8% | 218 | 24 | 566.5 | 25.5 | 4.5% | 202.8 | 1.6 |
| 5:00 - 5:15 | 195 | 67 | 392.7 | 29.7 | 7.6% | 312 | 76 | 612.6 | 19.4 | 3.2% | 219.9 | 1.6 |
| 5:15 - 5:30 | 251 | 77 | 362.4 | 34.6 | 9.5% | 346 | 68 | 671.1 | 47.9 | 7.1% | 308.7 | 1.9 |
| 5:30 - 5:45 | 188 | 48 | 330.9 | 17.9 | 5.4% | 312 | 55 | 686.2 | 40.3 | 5.9% | 355.3 | 2.1 |
| 5:45 - 6:00 | 190 | 57 | 284.9 | 18.3 | 6.4% | 333 | 60 | 526.1 | 45.8 | 8.7% | 241.2 | 1.8 |
| 6:00 - 6:15 | 167 | 42 | 286.7 | 19.4 | 6.8% | 297 | 48 | 473.3 | 36.6 | 7.7% | 186.6 | 1.7 |
| 6:15 - 6:30 | 144 | 38 | 230.3 | 22.7 | 9.9% | 317 | 52 | 294.9 | 71.4 | 24.2% | 64.9 | 1.3 |
| 6:30 - 6:45 | 107 | 39 | 199.9 | 6.4 | 3.2% | 292 | 69 | 207.9 | 6.6 | 3.2% | 8.0 | 1.0 |
| 6:45 - 7:00 | 91 | 22 | 203.2 | 7.9 | 3.9% | 233 | 53 | 209.2 | 7.4 | 3.5% | 6.0 | 1.0 |

* Excluding Transit Buses

◆

For additional company information, please contact:

Jeffrey Woodson
(713) 952-7494

Paul Shuldiner, Ph.D.
(713) 952-7495

Salvatore D'Agostino
Computer Recognition Systems, Inc.
(617) 491-7665

# Transfomation Systems, Inc.

## Intelligent Transportation Systems (ITS) Services

### Automated Video-Based Computer Systems

- Traffic monitoring and vehicle classification systems (TAS2) developed by Computer Recognition Systems to automatically count and classify vehicles using CCTV cameras and machine vision technology

- Origin-destination and journey time surveys to automatically perform travel surveys for determining traffic patterns, trip times, congestion delays, and performance of HOV facilities using portable Hi-8 video cameras and license plate recognition. Where DMV records are available, a database is created for use in mailouts and other survey information.

- SVDD (Speed Violation Detection/Deterrent) is a video-based system used to measure vehicle speed and identify violators using license plate recognition

- HOVER (High Occupancy Vehicle lane Enforcement and Review) is used to remotely monitor HOV lanes and identify violators using cameras and computers

- Security cordon and border crossing surveillance using CCTV cameras and automatic license plate recognition to identify and monitor frequent or recurring threats and incidents involving vehicles

*Transfomation Systems, Inc., 2537 South Gessner, Suite 212, Houston, Texas 77063*

# *Transfomation*
# *Systems, Inc.*

# Intelligent Transportation Systems (ITS) Services

## Automated Video-Based Systems

- *Traffic Monitoring & Classification*
- *Automatic O-D & Journey Times*
- *Speed Enforcement System*
- *HOV Lane Enforcement System*
- *Security Cordon & Border Crossings*